

Ground Measurements of surface Bidirectional Reflectance Factor (BRF) using The Portable Apparatus for Rapid Acquisition of Bidirectional Observation of the Land and Atmosphere (PARABOLA III)

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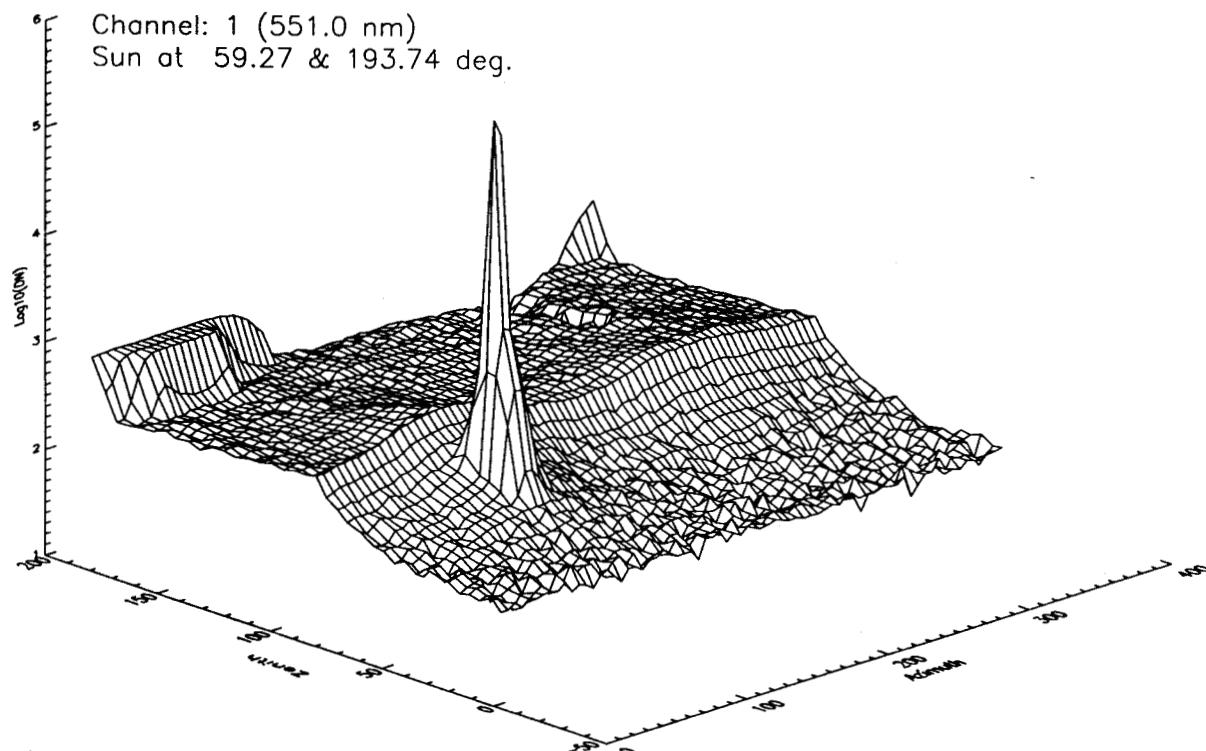
The Portable Apparatus for Rapid Acquisition of Bidirectional Observation of the Land and Atmosphere III

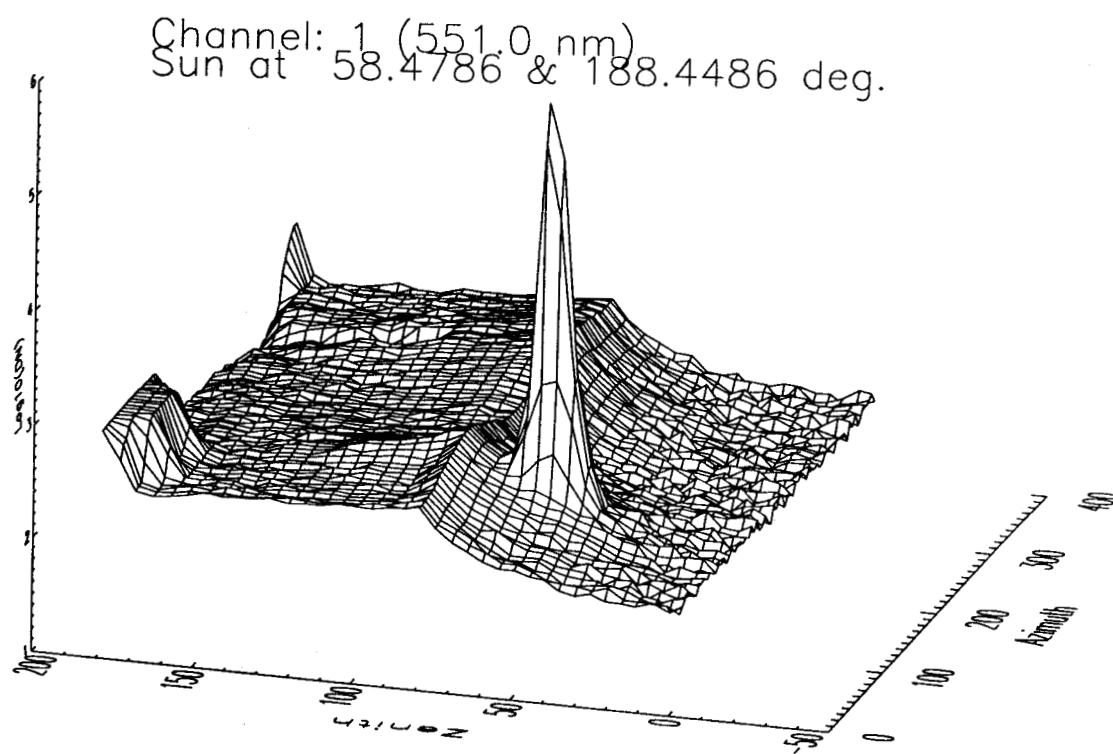
- Sky and surface-reflected hemispheric radiance distribution.
- Complete hemispheric radiance distribution, in 5° field-of-view.
- 6 channels + one broad band, 443 - 1655 nm.
- Data provide the bidirectional reflectance factor (BRF) and the hemispherical directional reflectance factor (HDRF).

- **The surface Bidirectional Reflectance Factor (BRF):**

The ratio between the radiance reflected from the surface to that reflected from a perfect Lambertian reflector under the same direct illumination.
- **The surface Hemispherical Directional Reflectance Factor (HDRF):**

The ratio between the radiance reflected from the surface to that reflected from a perfect Lambertian surface illuminated under the same atmospheric conditions.





• Analytical Spectral Devices (ASD) Portable Spectrometer:

- Surface-Reflected Radiance- 350 - 2500 nm, $\Delta\lambda \approx 7 nm$.
- Provides retrieval of surface hemispherical directional reflectance, HDRF, (includes diffuse light) when compared with spectralon standard reflectance panels.

• Reagan-c Sun Photometer:

- Optical Depth

• Solar Irradiance:

- Best available Spectral Solar irradiance Data published in the World Climate Program (WCRP) Publication Series No. 7, WMO ITD-No. 149, pp 119-126

The measured upwelling radiances at the surface, are expressed as:

$$\hat{L}(-\mu, \mu_0, \varphi - \phi_0) = \pi^{-1} \int_0^1 \int_0^{2\pi} R(-\mu, \mu', \phi - \varphi') L^{inc}(\mu', \mu_0, \varphi' - \phi_0) \mu' d\mu' d\phi' \quad (1)$$

Equation 1 can be written in terms of the direct and diffuse incident radiances as follows:

$$\hat{L}(-\mu, \mu_0, \varphi - \phi_0) = \pi^{-1} R(-\mu, \mu_0, \varphi - \phi_0) E_{dir}(\mu_0) + L_{diff}(-\mu, \mu_0, \varphi - \phi_0), \quad (2)$$

where, L_{diff} is given by:

$$L_{diff}(-\mu, \mu_0, \phi - \phi_0) = \pi^{-1} \int_0^{12\pi} \int_0^{\pi} R(-\mu, \mu', \phi - \phi') \hat{L}_{diff}^{inc}(\mu', \mu_0, \phi' - \phi_0) \mu' d\mu' d\phi', \quad (3)$$

and,

$$E_{dir}(\mu_0) = \mu_0 \bar{E}_0 e^{(-\tau)/\mu_0} \quad (4)$$

where, \bar{E}_0 is the PARABOLA band-weighted exo-atmospheric solar irradiance, τ is the total optical depth measured by the Reagan sun-photometer. An iteration method has to be used to retrieve R. The iteration process starts by assuming $L_{diff}^0 = 0.0$

Therefore, from equation 2, the first iteration for R is,

$$R^1(-\mu, \mu_0, \varphi - \varphi_0) = \frac{\hat{L}(-\mu, \mu_0, \varphi - \varphi_0) - L_{diff}^0(-\mu, \mu_0, \varphi - \varphi_0)}{\pi^{-1} E_{dir}(\mu_0)} \quad (5)$$

Substituting this first guess for R^1 , and the PARABOLA data of the downwelling diffuse radiance, into equation 3, we solve for the first iteration for L_{diff} ,

$$L_{diff}^1(-\mu, \mu_0, \varphi - \varphi_0) = \pi^{-1} \int_0^{1/2\pi} \int_0^1 R^1(-\mu, \mu', \varphi - \varphi') \hat{L}_{diff}^{inc}(\mu', \mu_0, \varphi' - \varphi_0) \mu' d\mu' d\varphi' \quad (6)$$

It should be noted that in equation 6, μ' is an array of incident angles, therefore, $R^1(-\mu, \mu_0, \phi - \phi_0)$ which is calculated from equation 5, is an array calculated using the PARABOLA data for the upwelling surface radiance at all values of μ_0 and $\phi - \phi_0$, in the integration range (this, however, may not always be possible and other techniques to extrapolate the data at missing sun angle range are used.) The first calculated value L_{diff}^1 is then substituted in equation 2 to calculate the first iterative value for the upwelling radiance,

$$L^1(-\mu, \mu_0, \phi - \phi_0) = \pi^{-1} R^1(-\mu, \mu_0, \phi - \phi_0) E_{dir}(\mu_0) + L_{diff}^1(-\mu, \mu_0, \phi - \phi_0) \quad (7)$$

which is then compared with the measured upwelling radiance $\hat{L}(-\mu, \mu_0, \varphi - \varphi_0)$.

The above steps are repeated, where for the n^{th} iteration, equation 5 can be expressed as:

$$R^n(-\mu, \mu_0, \varphi - \varphi_0) = \frac{\hat{L}(-\mu, \mu_0, \varphi - \varphi_0) - L_{diff}^{n-1}(-\mu, \mu_0, \varphi - \varphi_0)}{\pi^{-1} E_{dir}(\mu_0)}$$

The iteration process ends when

$$\varepsilon^n = \frac{L^n - \hat{L}}{\hat{L}} \leq \varepsilon_0$$

where, ε_0 is a predetermined small number which depends on the required accuracy for the retrieved BRF.

